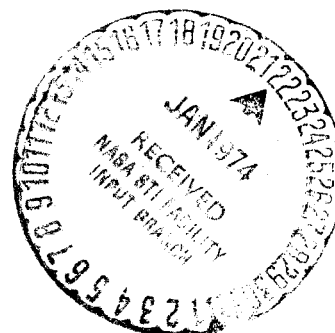


THE SELECTION OF SOVIET COSMONAUTS

Academy of Sciences USSR

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Even before man's accomplishment of the first orbital flight, in order to /1* solve the many problems related to man's conquest of outer space an extremely complex and responsible task of selecting persons suitable with respect to health for the new type of activity arose.

The first step in the solution of this problem was the attempt to find certain already approved systems of medical selection of persons for work under conditions only approximating those of spaceflight. The system of medical selection already used by aviation medicine was most suitable for this goal.

Hence, the medical selection of candidates for cosmonaut duty underwent its development based upon the developed and approved system of medical selection and examination of flight personnel.

Subsequently, proportional to obtaining reports on the influence of space-flight factors on the human organism, the system of medical selection of cosmonauts was improved, and was modified, acquiring an independent trend.

Toward the beginning of making selection it was known that flight in space is accompanied by exposure of the organism to a number of factors: accelerations, vibrations, noise, weightlessness, long term isolation, relative hypodynamia, disorder of the diurnal rhythm, etc.

Inasmuch as the path of direct experimentation with the participation of people was excluded during this period, there remained a single, and as it subsequently turned out, correct path of carrying out a penetrating clinical and physiological investigation using a broad complex of load tests for comprehensively estimating the somatic sphere and functional capacities of the /2 organism. The positive solution of this problem was to a great extent made possible by many years of experience in medical and flight expertise.

*Numbers in the margin indicate pagination in the foreign text.

Thus, the first cosmonauts were selected from among members of flight personnel. It was assumed that the first cosmonauts had to be people who, in addition to being in good health, had to have a strong will, rapid reactions, the capacity to make decisions in unexpected situations and to rapidly execute these decisions. The cosmonauts had to be people familiar with flight conditions and with the influence of factors similar to those which could be encountered in spaceflight. Persons who had these qualities could be found, with a high degree of probability, among flight personnel.

The complexity of the conditions of a spaceflight, testing space equipment and conducting various scientific investigations for conquering space required including the cosmonaut investigators in the crew of spacecraft; these had to be persons of high scientific qualifications. In this regard, it became necessary to introduce the corresponding correction in certain criteria for evaluating the condition of health of the selected candidates, as well as to verify certain problems pertaining to selection, and, particularly to the training of cosmonauts and investigators, in comparison with the first cosmonauts.

The specific character of the medical selection of cosmonaut investigators was explained by the characteristics of their age and by the deficient level of physical training. At the same time, it was necessary to take into account their professional value as highly qualified specialists.

In the plan of the investigations which were used in the given case in selecting cosmonaut investigators, there was no specific difference and what difference there was consisted more in interpreting the data obtained when determining the functional reserves of the candidates' organism, and also in what improved prophylactic medical measures it was necessary to carry out to provide their optimal medical support. Moreover, it was important to have a thorough conception of whether or not there were any peculiarities in the reactions which could unfavorably affect the activity of the future spacecraft crew member. /3

Hence, taking into account the professional value of the cosmonaut investigators and their range of duties in the flight, it turned out to be possible to

permit the accomplishment of training of the candidates with certain deviations in the condition of health.

The subsequent preflight analysis of data elected at all stages of selection, as well as the materials presented by clinicians, physiologists and psychologists provided a basis to recommend those candidates who were best prepared and who had a good resistance to the influence of spaceflight factors, inasmuch as these data permitted one to predict adequate tolerance of the cosmonaut or group of cosmonauts for successfully completing the flight. In the meantime, the observed changes in certain organs and systems of the organism during various tests remained the subject for careful observation in all stages of training and in spaceflight, with the goal of further improving the system of selection and training. A further search for means of active prophylaxis is also being continued, and more rational indices for employing such measures prior to flight, during flight, and the period of restoration of those functions disturbed in the actual flight are being developed.

During formulation of the Soviet system of medical selection of cosmonauts, the starting point was the concept that the selection of the cosmonauts is a /4 continuous process.

The developed system of selecting cosmonauts planned for several inter-related stages:

- examination and selection under ambulatory conditions;
- examination and selection under clinical conditions;
- examination and selection in the process of training.

The ambulatory stage was directed toward revealing clear pathology and those functional disorders which are absolutely contraindicated for admission to spaceflight.

Selection under clinical conditions planned for revealing their concealed pathology, the initial preclinical forms of diseases, changes in the functional conditions of the organs and systems of a man, and the determination of functional reserves of the organism.

Preliminarily, the created program of clinical examination consisted of two parts. The first part contained provisions to conduct investigations in the

plan and volume of medical expertise of flight personnel with the imposition of the same requirements on the state of health which are made on candidates for flying schools.

The candidates, having completed the first part of the examination with positive results, were admitted to the second stage of examination, which pursued the goal of revealing the reserve capacities of the organism through the use of a number of load tests as specifics for the professional activity of the cosmonaut (the centrifuge test, vestibular tests, etc.), as well as non-specific tests (tests with physical load, etc.). In addition to this, supplementary clinical examination was conducted which was directed toward revealing possible latent pathology.

Psychological examinations had a significant place in medical selection. /5 They were directed toward revealing the characterological characteristics of personality, predicting behavioral and emotional reactions under conditions of stress. By the aid of experimental psychological investigations based upon a combination of individual and group methods, estimation of the interactions of people in the process of group joint activity was made. It was borne in mind that these data subsequently would be used in assigning crew members of spacecraft according to the principle of their compatibility.

As an analysis of the clinical data showed, persons who passed all stages of selection and were recognized as suitable for flight were healthy people who demonstrated good resistance to the load functional tests. The selected candidates were then sent to the Cosmonaut Training Center to undergo specific flight training. The primary role of this training was to increase the resistance of the organism and to develop adaptive reactions to the effect of specific factors of spaceflight, and also to acquire necessary working skills in controlling systems and instruments of the spacecraft.

When making the selection of cosmonaut candidates, at all stages, and particularly under clinical conditions, a significant portion of the candidates were rejected in connection with findings of health defects in their condition. In various years, from 25 to 50% of the candidates who had gone through the initial selection process were rejected. The primary reasons were functional

disorders and diseases of the internal organs. Moreover, conclusions of unsuitability were made regarding candidates in whom diseases of the eye, nose and throat were found, and in whom anomalies of development or degenerative changes of the spinal cord were found, as well as those who had vestibular-vegetative instability. /6

In recent years, rejection in the second stage has diminished thanks to a stricter approach during the preliminary examination, and to the application at this stage of new methods of investigations. Thus, for example, the replacement of standard vestibular tests determining the effect of cumulative vestibular stimuli by Coriolis acceleration has significantly decreased the rejection of candidates for reasons of vestibular disorders (Bryanov, I. I., 1963).

The Soviet data and investigations of scientists of other countries show that in weightlessness and under conditions of limited movement, the characteristic changes in the human organism for spaceflight are disorders of the water electrolyte and hormonal balance, as well as disorders of the vascular tonus, decreased tolerance for physical stress and radial accelerations.

A prolonged stay in a state of weightlessness can make possible the development of a number of disorders of the cardiovascular system. The emotional stress natural for cosmonauts in flight is also of significance, as are the stress reactions which can arise in the process of professional activity, particularly during long space expeditions. All this required introducing certain corrections into the methodology of medical selection based on an analysis of the results of clinical and physiological investigations both in a state of rest and when carrying out physical tests under conditions simulating the factors of spaceflight. Such a clinico-physiological approach enabled more active estimation of the functional capacities of the organism, the range of its resistance to extremal factors, and made possible determination of the compensator adaptive mechanisms.

The experience acquired in actual spaceflights, in addition to the before mentioned volume of terrestrial investigations conducted, made it possible to lay the groundwork for and systematize certain criteria for medically expert estimation of the condition of health and physical standards of cosmonauts /7

being trained for spaceflights. The medically expert approaches were determined both with respect to the most frequently encountered and isolated pathological conditions, and with respect to limited and latently-running forms of illnesses and disorders revealed among cosmonaut candidates. The latter pose a great deal of difficulty for their interpretation with respect to the tasks of selection.

It is known that endocrine disorders can serve as the reason for functional deficiency of the cardiovascular system under stress conditions. Therefore, the diagnosis of latent endocrine deficiency, specifically the determination of individual symptoms of hyper- or hypofunction of the endocrine glands, even without detecting pronounced signs of disorders in the state of health, is a serious argument placing under doubt the suitability of the candidate to participate in a long term spaceflight. In this regard, a disorder of the lipid metabolism, of endocrine origin, must be viewed as a contraindication for long term spaceflight. Persons with elementary corpulanc^{ce}~~e~~ of the second degree also cannot be considered as promising candidates for cosmonaut activity primarily because they are subject to early atherosclerosis. Underweight persons are also undesirable, inasmuch as they are more subject to a decrease of working capacity as the result of the loss of fluid under the unfavorable conditions of living aboard the spacecraft.

Loss of fluid and other disorders of the water and electrolytic balance are among a number of the main etiological causes for a decrease in the orthostatic stability (Giovanni, Birkft, 1964; Lauton, 1962).

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According to the data of P. V. Vamil'yev, O. G. Gazenko, A. R. Kotovskaya and others (1962), a factor which limits the process of adaptation to weightlessness is a decrease in orthostatic stability specifically related to a change in afferentation as the result of a significant decrease in the hydrostatic pressure of the blood under these conditions. Redistribution of blood in the central and peripheral regions of the organism causes a decrease in the volume of the circulating blood.

Disorders of the water-salt metabolism related to motionlessness and weightlessness can lead to the formation of stones in the urinary system — a fact confirmed by clinical data.

Kauket, Bechler and Roberts (1962) reported detecting renal complications in 15 of 44 patients (35%) following long term limited movement. In 12 men, an increased excretion of phosphorus led to the formation of phosphate stones which was related to decreased muscular activity.

Naturally, persons should not be admitted to spaceflight who have an anamnesis renal colic, disease of the gall bladder, hematuria of unknown etiology, hyperphosphatemia, oxaluria, goiter or false goiter (i.e., conditions for suspicion of presence of a tendency to the formation of stones).

With the goal of revealing latent forms of kidney stone illness, in addition to the usual clinical methods, including intravenous pyelography, additional methods were also used designed to check the "provocative" effect of such professional factors as radial accelerations and vibrations. The investigations of the components of urine before and after the indicated exposures enabled, additionally, detection of latently occurring forms of uroliphaise. With the goal of improving this trend, further searches for ways and means of determining /9 the predistribution of subjects to kidney stone illness are necessary.

The character of functioning of the cardiovascular system under conditions of prolonged immobility and weightlessness gives every reason for conducting a most careful estimation of the resistance of the organism to stress factors, particularly among persons in whom any particular disorders of the cardiovascular system have been detected.

Disorders of the nervous system and circulatory system, which can appear in spaceflight, also include disorders in the system of stimulation and conductivity of the heart. These are given great significance in the practice of selecting cosmonauts. When solving the problem of the suitability of cosmonaut candidates in whom disorders of the cardiac rhythm are recorded, the basic criterion is the frequency, localization and nature of appearance of the extrasystole.

A large role in the occurrence of extrasystole is played by overstimulation of the parasympathetic innervation of the heart. Extrasystole, related to an increase in the tonus of the vagus nerve, usually appears under conditions of good functional condition of the myocardium, and most frequently is of left

ventricular origin and has no particular influence on the circulation. Such extrasystoles are encountered, as a rule, in a state of rest, with a diminished pulse and are scattered in nature. Such persons endure functional load tests well. Under the influence of atropine or physical loads, extrasystoles usually disappear, which indicates their functional character. With respect to predicting the significance of various types of extrasystoles, the most significant among them are those of the auricle and atrioventricular extrasystoles.

Clinical observations show that in an extrasystole of the auricle, as a rule, there are significant morphological changes in the auricles (L. I. Fogel'son, 1957, and others). Atrioventricular extrasystole gives even greater reason to assume the presence of damage to the myocardium. Here one should take into account that auricular and atrioventricular extrasystoles are frequently precursors of paroxysmal tachycardia and flickering arrhythmia (L. I. Fogel'son, 1957, A. M. Sigal, 1958 and others). /10

Polytopic and group extrasystoles, as well as stress extrasystoles appear, as a rule, as the result of inflammatory and atherosclerotic injuries to the myocardium and can lead to disorders of the circulation, while frequent atrioventricular extrasystoles can lead to retrograde contraction of the auricles. Candidates with such forms of extrasystole should not be recognized as suitable for the professional activity of the cosmonaut.

In the practice of selecting candidates, there was also occasion to observe persons with various disorders of the conductive system of the myocardium.

Persons with retarded atrioventricular conductivity along the P - P interval on the EKG of up to 0.22 seconds were considered suitable, if during the test with standing (the orthostatic test), conductivity was not retarded even more and if, by the aid of atropine and physical exercise, the duration of conductivity did not shorten. An extension of the QP interval to 0.11 seconds among persons with good tolerance during load tests was also not a basis for concluding that they were unsuitable.

In connection with the fact that during hypokinesia and in weightlessness there occurs a loss of catecholamines and aldosterone, one observes a decrease in the arterial blood pressure as the result of decreased vascular tonus. This

leads to the threat of orthostatic hypotension. As a result of this, persons with stable orthostatic hypotension below 100/55 mm Hg were not admitted to spaceflights. /11

Constant arterial pressure, which periodically decreases, was evaluated individually, taking into account the results demonstrated during tests under stress conditions. Persons with hypotony and a predisposition to collaptoid reactions under conditions of stress factors are unquestionably unsuitable for spaceflight.

Persons inclined to hypertensive reactions with respect to the arterial pressure also require careful differentiation. One occasionally encounters subjects in whom high figures of arterial pressure are recorded first under clinical conditions. Such cases can be explained by the influence of the emotional factor. However, when establishing a tendency to strengthening of these hypertensive reactions among candidates, the latter should be recognized as unsuitable. Such an expert approach to the indicated group is made necessary by the leading role of emotional influences and psychological stress, with which the professional activity of the cosmonaut is saturated, in the development of disorders of the vascular tonus, and also by the prediction significance of frequent increases in the arterial pressure of the norm in the development of subsequent hypertonic disease. Naturally, the candidates in whom disorders of the heart valves and other pronounced pathology were found were recognized as unsuitable.

The accumulated data on the effect of spaceflight factors on the human organism and the experimental studies of individual flight factors made it possible to detect certain changes in various systems and organs. In clinically healthy people, the functional limits differ individually, and these limits characterize the tolerance to flight conditions. Therefore, a final conclusion /12 on the suitability of any particular candidate for spaceflight is made on the basis of a complex evaluation of the state of health according to the results of clinical investigations and by the way the candidates tolerated the functional load tests.

According to the data of M. D. Vyadro et al., (1967) and of others, and Krupina, T. D. et al., (1972), the most informative of these tests are tests

with physical load, orthostatic tests, hypoxic and thermal tests. It should be added, that in the future the value of these methods will increase proportional to how unified the system of evaluation becomes, proportional to how a system comparison of the data obtained under terrestrial conditions is conducted against the results of actual stress factors under the actual conditions of spaceflight.

The accumulated experience and analysis of many observations gives one basis to hypothesize that certain deviations in the state of health found among the cosmonauts may not have a negative effect on fulfilling even long term spaceflights, if, when conducting the functional load tests and when simulating certain flight factors these persons do not develop disorders of the adaptive capacities of the organism.

Among the latently occurring forms of diseases of the internal organs, gastrointestinal pathology occupies an important place. Ulcer disease and angiocholitis are among the potentially dangerous diseases of the gastrointestinal tract with respect to the profession of the cosmonaut, inasmuch as these diseases (unquestionably incompatible with the activity of the cosmonaut) in a number of cases occur asymptotically, being revealed only in the form of a decrease in the organism's resistance to the effect of functional load tests and, specifically, to hypoxia, vestibular stresses, etc. This is why /13 diagnosing diseases of the gastrointestinal tract at the hospital stage of selection was given great attention. In addition to a more careful and goal-directed study of the anamnestic data, with the use of widely used methods of clinical diagnosis, investigations were conducted which were directed toward expanding the diagnostic possibilities of revealing preclinical forms of gastrointestinal diseases (Ye. A. Fedorov, 1967).

Among the great variety of diseases pertinent to the realm of surgery which require an individualized approach to their expert evaluation, degenerative and dystrophic changes of the spinal cord deserve attention. Decisive significance in their diagnosis doubtlessly belongs to the x-ray method. This is specifically due to the fact that in an overwhelming majority of cases the indicated diseases occur asymptotically, causing neither the pain syndrome nor any significant disorders of statics and movement of the spinal cord.

During the clinical evaluation of degenerative and dystrophic diseases of the spinal cord, a great deal of significance was given to the condition of the static and dynamic functions of the spinal column. This acquired particular significance in regard to candidates recognized as suitable, since the indicated data served as certain additional indices of the overall physical conditioning of the organism, and consequently, during the subsequent dynamic observations could be used in the capacity of one of the criteria for evaluating the correctness of the structure of the system of special physical training. With this goal, in the practice of selection, wide use was made of gonometry [Translator's Note: sic], making it possible objectively to record not only the configuration, but also the amplitude of movements in various regions of the spinal column.

The gonkometric [Translator's Note: sic] measurements which were conducted showed that among a number of candidates with deforming spondylitis and osteochondrosis, an important clinical sign was detected, namely a limited inclination of the trunk toward the back.

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Expert opinions in that case were formed taking into account the character of the upcoming activity, the degree of pronouncement of the morphological changes in the spinal column and the condition of its function. One should bear in mind, however, that the latter fact is of relatively expert value [Translator's Note: sic] inasmuch as in these processes compensation of function is extremely unstable and easily be disrupted, particularly in the process of training on a large scale with various exercises (parachute jumps, physical exercises, etc.).

One of the primary characteristics of the physiological aspect of cosmonauts for long term flights, which is doubtlessly subject to development, is a correct evaluation of the complex system of "analyzers", which have developed in the process of human evolution, particularly the vestibular, visual and kinesthetic.

Under the conditions of spaceflight, as a result of the effect of specific factors (weightlessness, g-forces, etc.), this regular aspect can be disrupted, causing the development of various disorders among which the most unfavorable

are the vestibulo-vegetative. This is the reason the development of a methodology for vestibular selection was paid a great deal of attention.

As is known, many authors do not share the viewpoint that there is a direct relationship between the resistance of the vestibular apparatus to the effect of adequate stimuli received under terrestrial conditions and tolerance to flight. Together with this, all of the preceding test flights aboard the "Vostok", "Voskhod", and "Soyuz" spacecraft provide the grounds to consider that persons naturally resistant to the cumulative effect of adequate stimuli, and also persons trained to the appropriate complex of vestibular factors, /15 endure spaceflights without vegetative disorders and rapidly adapt to weightlessness.

The materials of these observations lay at the basis of development of a system of vestibular selection, also determining the expediency of specially trained cosmonauts by methods of active and passive training of the vestibular system.

Methods of vestibulometry for purposes of selecting and training based upon the complex effect of Coriolis accelerations, linear accelerations (Khilov swings), and also methods of applying optokinetic stimuli in combination with load on the statokinetic system by means of balancing on a measured variable nonstable fulcrum have been developed.

The vestibular problem on the whole and its aspects specifically pertaining to training and selection maintained their urgency in the subsequent plan for carrying out long term spaceflight, particularly when it is necessary to create spacecraft having artificial force of gravity (the author has in mind the effects of Coriolis accelerations on man; these accelerations appear in rotating systems which provide a gravitational effect).

Hence, the experience of orbital flights has shown that the chosen system of selecting cosmonauts for short term flights has fully justified itself. The methodology of selecting the first cosmonauts was based upon vast experience in medical and aviation expertise, upon fundamental investigations carried out by specialists in aviation medicine, and was supplemented out by observations and experiments of clinicians as well as by the practice of actual manned spaceflights.

Notwithstanding the fact that in the course of establishment the system of selecting cosmonauts underwent a certain reevaluation of requirements on the condition of health of the cosmonaut investigators with respect to a decrease /16 in these requirements, as Soviet scientists propose, this tendency will hardly be extended to candidates selected for long term spaceflights. This is caused by the long term effect of flight factors on the organism of cosmonauts, by an expanded range of duties, which will be extended to all crew members, and the necessity for interreplaceability of cosmonauts during the flight will more realistically appear. All this requires introducing stricter criteria into the selection system with respect to evaluating the somatic and psychological spheres, to giving more improvement to determining the functional capacities of the organisms of persons selected for prolonged space expeditions. The subsequent development and the foundation of requirements for the state of health of candidates for cosmonaut positions and of cosmonauts should be based upon a study and analysis of scientific facts and clinical observations pertaining to the effect of conditions of spaceflight on the human organism.

In the near future, proportional to the increase in duration of spaceflights, other specialists besides pilots will undoubtedly be needed: navigators, engineers, physicians, biologists, astronomers, geophysicists, etc. This requires the development of new medical and psychological methods of selection, and improvement of the system as a whole. Moreover, with the goal of preserving the health of the cosmonauts and maintaining a high level of their functional capacities, it is necessary in the process of general training of cosmonauts to carry out goal-directed and systematic medical control, which will make it possible to estimate the functional reserves and adaptive reactions, i.e., all those things which determine the tasks of the next stage of selection. At this stage, skills in overcoming difficulties of the new professional activity are intimately intertwined with the development of resistance to spaceflight fac- /17 tors. In this regard it is necessary to mention that in the process of training a careful analysis of illness rate and physicians consultations of persons passing through the training cycle was carried out. This analysis carried out in comparison with the data of a control group specifically showed that the structure and character of the illness rate among cosmonauts during

the training period does not reveal any nosological forms of disease which could be attributed to occupational hazards in the training system.

In conclusion it should be mentioned that the system of selecting cosmonauts will be constantly improved, taking into account flight peculiarities, the modern achievements of general medicine, space medicine, and the general level of the biological sciences.

Such an approach to improving the system of selection and training makes it possible not only to make a prediction of good tolerance on the part of cosmonauts to the conditions of spaceflight, but also to provide for their high working capacity, successful completion of the flight, and safe return to the Earth.

For this purpose it is necessary to apply undiminished efforts to the study of conditions of long term flight and to the influence of spaceflight factors on the human organism.

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